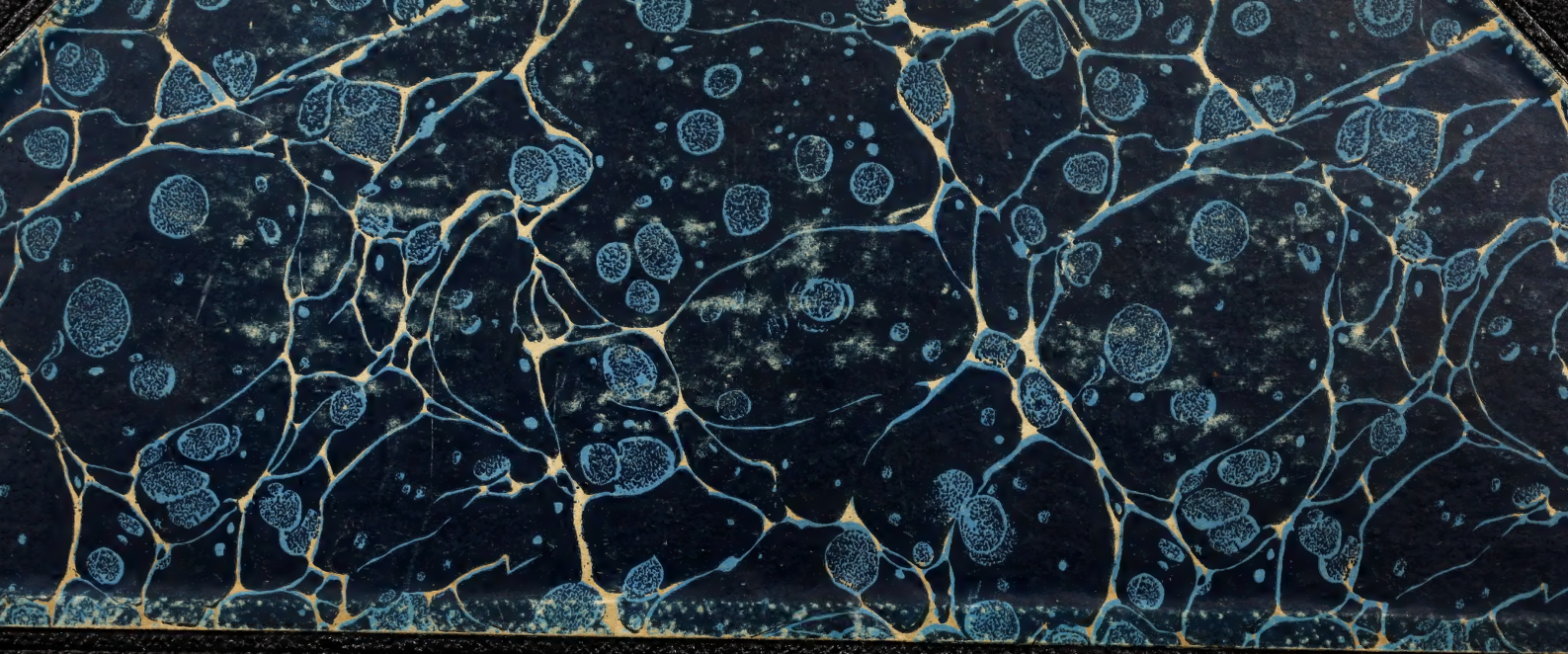

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THE INFLUENCE OF RELATIVE HUMIDITY AND MOISTURE CONTENT OF WHEAT ON MILLING YIELDS AND MOISTURE CONTENT OF FLOUR.

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INTRODUCTION.

It is common knowledge among millers that the total weight of the products obtained in milling almost invariably differs from the weight of the wheat used. This difference in weight is due largely to changes occurring in the moisture content of the wheat during its preparation for grinding and throughout the process of milling; therefore, any factor influencing the amount of moisture which becomes added to wheat or evaporated therefrom in its preparation for milling and during the different steps of milling influences to that extent the percentage yield of mill products.

The results of certain milling tests conducted in the experimental mill operated by the Federal Bureau of Markets and Crop Estimates at Washington, D. C., indicate the nature of some of these factors and the extent of their influence. Information was obtained on the following subjects: The influence of the relative humidity of the air within the mill and of the moisture content of hard wheats when

tempered to 15 per cent moisture on the invisible losses occurring during the milling process and on the total yield of mill products; also the influence of the temperature of the air within the mill upon the total yield of mill products.

HUMIDITY.

That the humidity of the atmosphere in the mill influences milling results is commonly known to millers. This influence, however, the miller is able to control to a certain extent by varying the tempering or conditioning process applied to the wheat and the manner of grinding and bolting, provided he can anticipate any change that is likely to take place in the humidity of the atmosphere. Advance information of the weather, however, can not always be depended upon; consequently, the miller can not always have his wheat conditioned and his mill adjusted properly for obtaining the highest degree of efficiency possible. Certain atmospheric conditions are generally recognized as being more conducive to good milling results than others; therefore, the installation of means for controlling the condition of the atmosphere within the mill would give to the miller a greater degree of control over the operation of his plant and thereby improve his results.

NORMAL MOISTURE CONTENT.

Evidence that an approximate parallelism exists between the moisture content of wheat and the relative humidity [1] of the atmosphere lies in the well-known fact that the normal moisture content of air-dry wheat is higher when stored in moist climates than when stored in dry climates. The term "normal" as used in this bulletin means that moisture content which is unaffected by continued exposure to the prevailing atmospheric conditions. In other words, it is that point at which equilibrium is established between the moisture content of the wheat and the humidity of the air. According to experiments by Stockham,[2] the moisture content normal for different wheats

[1] The amount of water vapor which can be mixed with a given quantity of air varies with its temperature; the higher the temperature, the greater the amount of water vapor it can hold. When air at a given temperature contains all the moisture possible for it to hold, it is said to be saturated. The percentage or ratio of the actual amount of moisture contained by a cubic unit of air to the amount which the same air would hold at the same temeprature if saturated is called the relative humidity. Relative humidity is usually stated in terms of percentage.

Since the capacity of the air for water vapor increases proportionately with temperature, every increase in temperature, assuming that the quantity of water vapor in the air remains the same, results in a lowering of the relative humidity, and every decrease in temperature results in a proportionate increase of relative humidity until the saturation point is reached, beyond which condensation occurs.

[2] Stockham, W. L., The Capacity of Wheat and Mill Products for Moisture. North Dakota Agr. Exp. Sta. Bul. No. 120, 1917.

and for their various mill products varies somewhat, even under the same atmospheric condition.

In milling, the practice of adding moisture to wheat in its preparation for grinding, which is usually referred to as tempering, may give to the wheat a moisture content above normal for the prevailing atmospheric conditions. Whenever this occurs and the wheat is exposed to the air, evaporation of this excess moisture begins. The quantity of moisture, however, actually evaporated from the wheat during milling is dependent upon a number of variables, including the quantity of moisture in excess of that normal for the prevailing atmospheric conditions, the distribution of the moisture, the length of time the material is exposed, the manner of exposure, the circulation of air, and the character of the material. Furthermore, because of the heat generated by the action of the various machines used in milling and other causes, the relative humidity of the air in different parts of the mill varies somewhat, affecting the rate and extent of the evaporation taking place at different steps in the milling process.

MATERIAL AND METHOD OF EXPERIMENTS.

The wheats used in the experiments conducted by the Bureau of Markets and Crop Estimates were milled on a special-type reduction machine, consisting of four pairs of 6-inch rolls, three corrugated and one smooth, together with a sifter and sieves appropriate for making the various separations of stock required. The quantity of wheat used in each test was 1,500 grams, or approximately 3 pounds. The wheats tested were hard wheats, representing various grades, qualities, and varieties, from various parts of the United States.

The system of milling used, although not the continuous automatic system employed in commercial mills, included all the various steps deemed necessary in modern milling practice. Figure 1 represents the flow sheet of the system used.

The time required to make each test averaged 1½ hours, which incidentally represents the period of time that each sample was exposed to the atmospheric conditions prevailing in the room in which the milling was performed. Before milling, each sample was cleaned, scoured, and tempered. No cleaning or scouring was performed after tempering. A determination of the moisture content of each cleaned and scoured sample was made previous to tempering. The tempering period ranged from 18 to 22 hours. The amount of temper water added depended upon the moisture content of the individual samples, enough being added to raise the moisture content to 15 per cent. During tempering, the samples were kept in air-tight cans which prevented any loss of moisture from the wheat from the beginning of the tempering period until the wheat started through

the first break rolls. In making the tests, care was taken to collect all the material ground. That some weight was lost through the

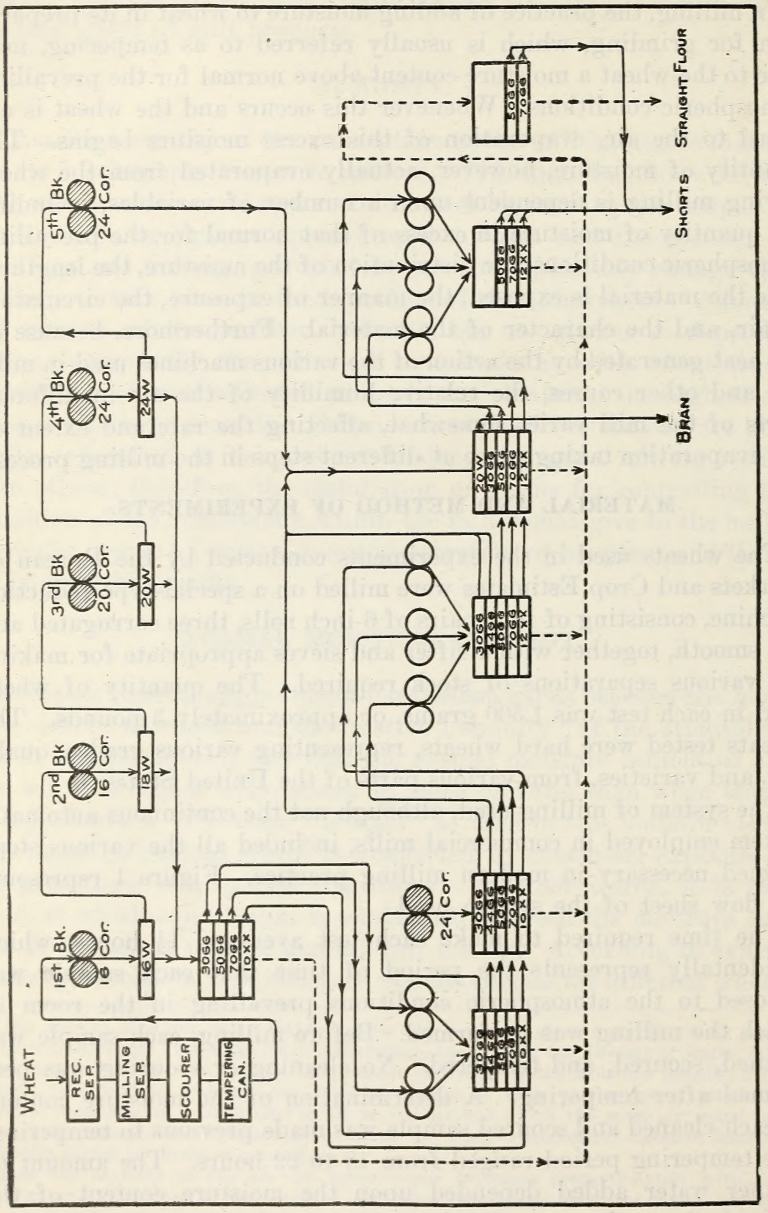

FIG. 1.—Flow sheet of experimental mill.

dusting out of fine particles into the air is quite probable, but the principal difference in weight between the wheat plus the temper water and the resultant mill products was due to evaporation during the process of milling.

The percentage yields indicated by the curves shown in the accompanying figures are based on the weight of the cleaned and scoured wheat samples before the addition of the temper water.

INFLUENCE OF RELATIVE HUMIDITY ON TOTAL YIELD OF MILL PRODUCTS AND INVISIBLE LOSS.

In figure 2 is shown the average total yield of mill products for various ranges of relative humidities. Because of the influence ex-

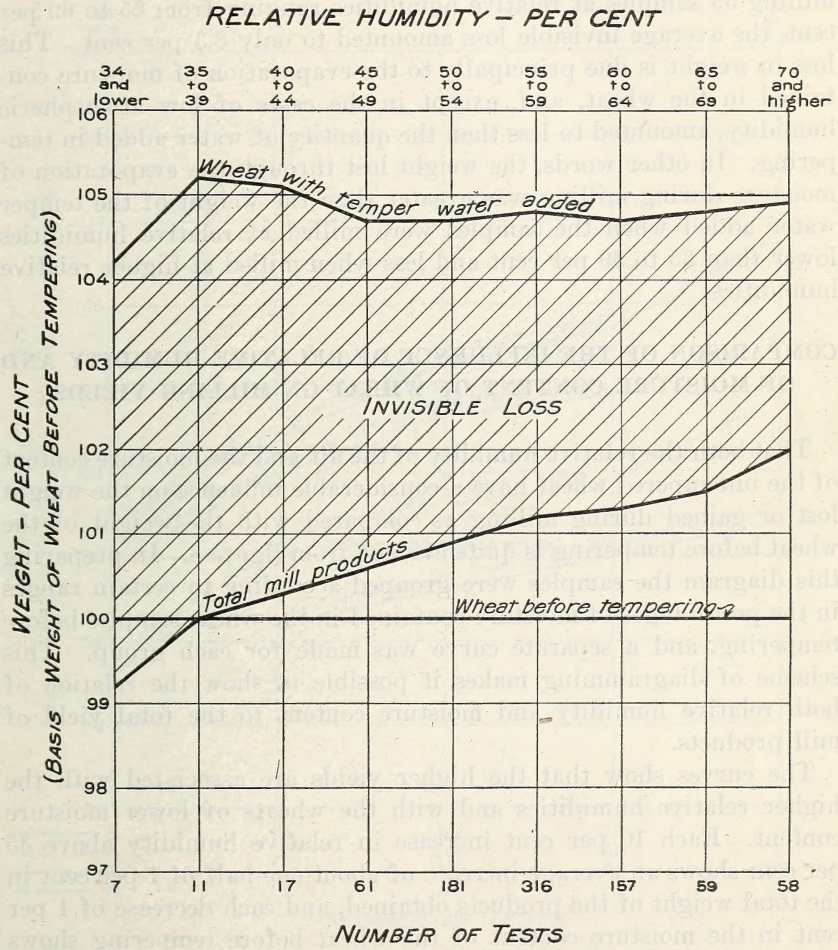

FIG. 2.—Showing that the invisible loss in milling decreases and the total weight of mill products increases with each increase in the relative humidity of the air within the mill.

erted on yields by the variation in the quantity of temper water which differences in the original moisture content of the various samples made it necessary to add in order to temper each of 15 per cent moisture, the curve shown represents the combined effect of relative humidity and moisture content of wheat on the total yield of mill

products. The shaded portion marked "invisible loss" is the difference in the weight of the wheat with the temper water added and the total weight of mill products obtained from milling. With each increase of relative humidity there is an appreciable decrease in the invisible loss occurring during milling and a proportionate increase in the total yield of mill products. For example, the average invisible loss resulting from milling 11 samples at relative humidities ranging from 25 to 29 per cent, inclusive, was 5.2 per cent, while in milling 59 samples at relative humidities ranging from 65 to 69 per cent, the average invisible loss amounted to only 3.3 per cent. This loss in weight is due principally to the evaporation of moisture contained in the wheat, and, except in the cases of low atmospheric humidity, amounted to less than the quantity of water added in tempering. In other words, the weight lost through the evaporation of moisture during milling was greater than the weight of the temper water added when the samples were milled at relative humidities lower than 35 to 39 per cent and less when milled at higher relative humidities.

COMPARISON OF THE INFLUENCE OF RELATIVE HUMIDITY AND OF MOISTURE CONTENT OF WHEAT ON MILLING YIELDS.

That both the relative humidity of the air and the moisture content of the untempered wheat have a considerable influence on the weight lost or gained during milling as compared with the weight of the wheat before tempering is quite evident from figure 3. In preparing this diagram the samples were grouped according to certain ranges in the percentages of moisture contained in the wheat samples before tempering, and a separate curve was made for each group. This scheme of diagramming makes it possible to show the relation of both relative humidity and moisture content to the total yield of mill products.

The curves show that the higher yields are associated with the higher relative humidities and with the wheats of lower moisture content. Each 10 per cent increase in relative humidity above 35 per cent shows an average increase of about one-half of 1 per cent in the total weight of the products obtained, and each decrease of 1 per cent in the moisture content of the wheat before tempering shows about six-tenths of 1 per cent increase in yield. Compared with the weight of the wheat before tempering, the samples containing from 9 to 9.9 per cent moisture showed a net gain in weight of total mill products for all relative humidities given, while the samples containing from 12 to 12.9 per cent moisture before tempering showed a net loss in weight of total mill products except for relative humidities higher than 60 to 69 per cent. The greatest average gain in weight

for any group was 3.8 per cent and the greatest average loss was 1.4 per cent.

In connection with the conclusions expressed in the preceding paragraph, it should be borne in mind that the increase in the total yield of mill products associated with the higher relative humidities was due, no doubt, to decreased evaporation during milling of the

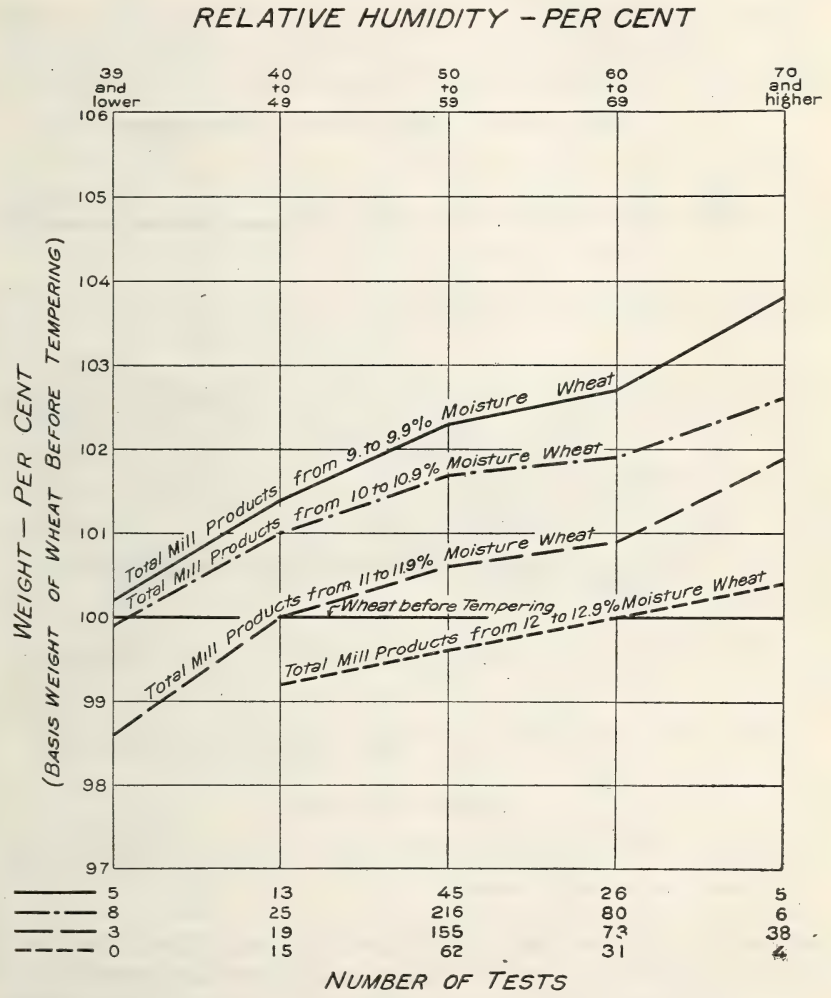

FIG. 3.—Relation of the relative humidity of the air within the mill and the moisture content of wheat to the total weight of mill products.

moisture contained in the wheat and in some cases to the absorption of moisture from the air by certain mill stocks, and, furthermore, that the increase in yields associated with the lower moisture content wheats was due to the greater amounts of water which it was necessary to add in tempering in order to bring the final moisture content of these wheats up to 15 per cent. The amounts of temper water

added to the samples, although not definitely stated in the diagrams, may be ascertained by subtracting from 15 per cent the percentage of moisture contained in the wheat before tempering.

INFLUENCE OF RELATIVE HUMIDITY ON MOISTURE CONTENT OF FLOUR.

Concerning the influence of atmospheric humidity on the moisture content of flour, Bailey[3] in his investigations on that subject concludes that "flour responds readily to changes in the humidity of

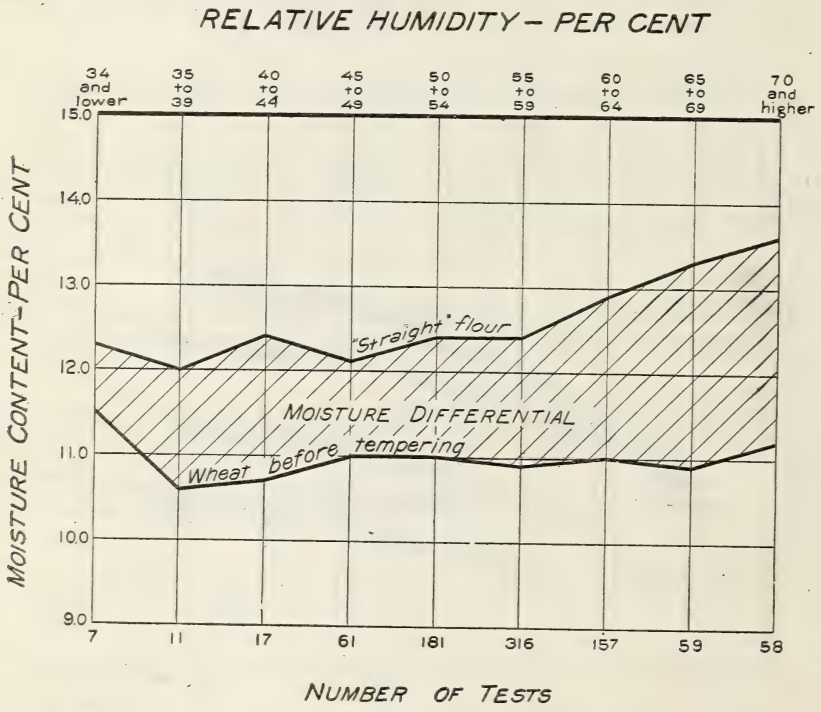

FIG. 4.—Showing that as the relative humidity of the atmosphere within the mill increases there is a corresponding increase in the moisture differential of the flour and of the wheat from which it is milled.

surrounding air, the rate at which equilibrium in moisture is approached depending apparently upon conditions of exposure."

An indication of the effect of relative humidity on the moisture content of the flour produced in connection with the experimental milling tests herein described is shown in figure 4. The results indicate a decided tendency for the moisture content of the flour product to be highest for the higher relative humidities. At relative humidities ranging from 35 to 39 per cent, the average

[3] Bailey, C. H. The Hygroscopic Moisture of Flour Exposed to Atmospheres of Different Relative Humidity, Journal of Industrial and Engineering Chemistry, vol. 12, No. 11, p. 1102. Nov., 1920.

moisture content of the flour produced was 12 per cent, and at 65 to 69 per cent relative humidity, the moisture content was 13.3 per cent, or an increase of 1.3 per cent moisture for a difference of 30 per cent in relative humidity.

It has been suggested that probably these are the normal moisture contents for flour at the respective relative humidities shown, but such a conclusion is not entirely justified, for the reason that in these tests no proof exists that the exposure of the flour to the air, which was limited to the length of time necessary for milling the sample, was sufficiently long to establish a state of equilibrium between the moisture content of the flour and that of the mill atmosphere. On the other hand, proof that at least some of these moisture contents are not normal is evidenced by the wide divergence from the results obtained by Bailey, to which reference has been previously made. For instance, he found that the hygroscopic moisture in flour in equilibrium with atmospheric humidity at 25° C. ranges from a little more than 5 per cent at 30 per cent relative humidity to 15 per cent at 60 per cent relative humidity.

COMPARISON OF THE INFLUENCE OF RELATIVE HUMIDITY AND OF MOISTURE CONTENT OF WHEAT ON THE MOISTURE CONTENT OF FLOUR.

Some indication of the comparative influence exerted on the moisture content of flour by each of the factors, atmospheric humidity and moisture content of the wheat before tempering, is given in figure 5. In this figure the results from samples which before tempering had moisture contents falling within various ranges are represented by separate curves. From this system of grouping it is possible to ascertain the particular influence exerted by each of these two factors. The proximity of the four curves to each other and their tendency to cross and recross each other indicate, for the method of tempering used in these experiments, no very pronounced relation between the moisture content of the flour and the moisture content of the wheat before tempering; or, in other words, no relation to the quantity of temper water added. On the other hand, a decided tendency is shown for the moisture content to increase as the relative humidity increases, a difference of 10 per cent in relative humidity making an average difference of approximately one-half of 1 per cent in the moisture content of the flour.

It would be interesting to know what influence, if any, variations in the final moisture content to which wheat may be tempered and the length of the tempering period would have on the resultant moisture content of the flour milled at different relative humidities. Since all samples were tempered to the same moisture content and for approximately the same length of time, it is impossible to draw any conclusions in regard to this influence from the results of these experiments.

Judging, however, from results obtained from other experiments, both the extent to which the moisture content of the wheat is raised in tempering and the length of time of tempering have an influence on the resultant moisture content of the flour product.

INFLUENCE OF ATMOSPHERIC TEMPERATURE ON THE TOTAL YIELD OF MILL PRODUCTS.

In addition to the influences of atmospheric humidity and moisture content of wheat, the possible influence of the temperature of the air within the mill on the total yield of mill products has also been

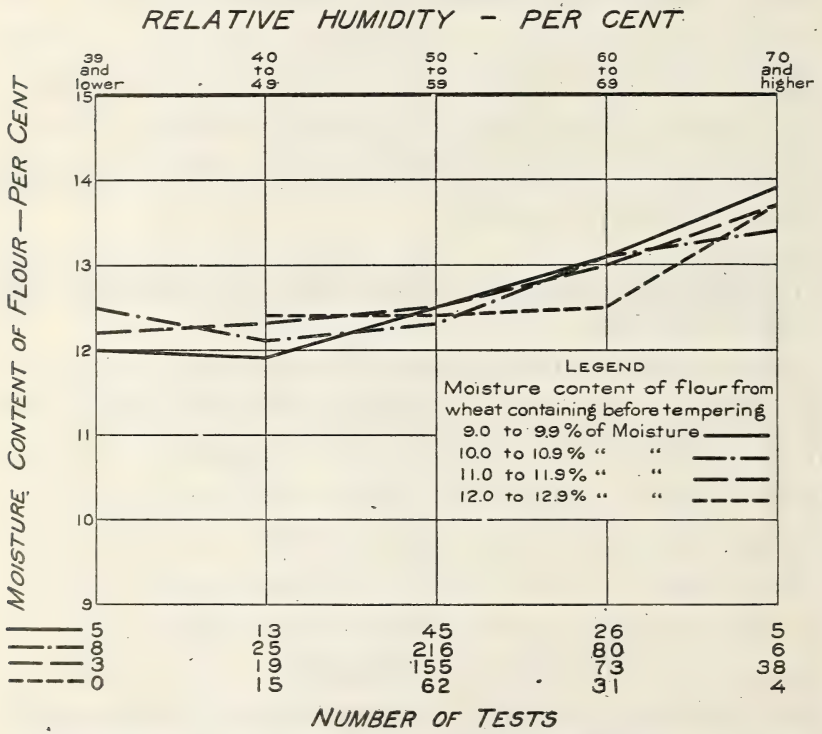

FIG. 5.—Relation of the relative humidity of the air within the mill and of the moisture content of wheat to the moisture content of the resultant flour.

given consideration and the results are represented by the curve shown in figure 6. In considering this factor, only the results obtained from those samples having approximately the same moisture content (10 to 10.9 per cent) before tempering, and which were milled at approximately the same relative humidity (50 to 59 per cent) were taken, in order that the results shown might be free from the influences of atmospheric humidity and moisture content. The curve in figure 6 shows the total yield of mill products obtained for various ranges of air temperature, and judging from the indefinite direction taken by this curve, no apparent relationship

between air temperature and yield of products can be established from the results of these investigations.

It is not contended that the experimental milling results given in this bulletin are entirely indicative of those occurring in commercial milling, but it is reasonable to believe that relative humidity and

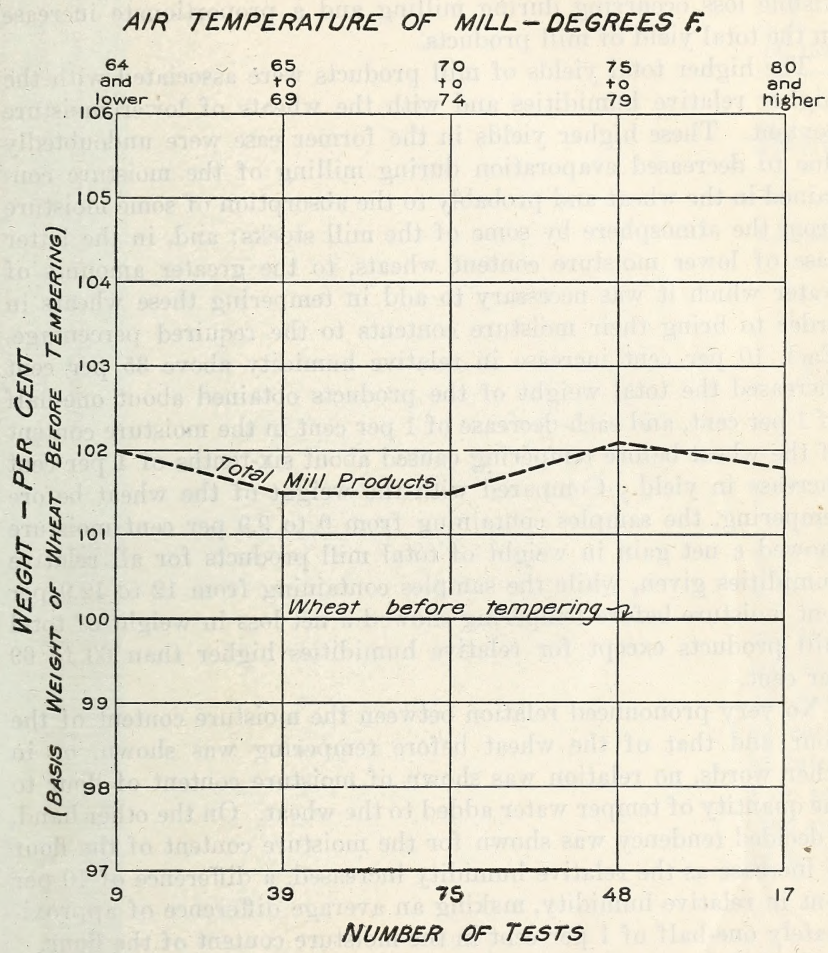

FIG. 6.—Relation of the temperature of the air within the mill to the total weight of mill products.

moisture content of wheat have a similar influence on the products of commercial milling plants, so that if any difference in influence does occur, it is only in degree and not in kind.

SUMMARY.

In brief, the conclusions that may be drawn from these experimental milling tests on hard wheats of various moisture contents, all

tempered to the same final moisture content of 15 per cent, are as follows:

With each increase of relative humidity or, in other words, with each increase in the extent to which the air within the mill became saturated with moisture, there was an appreciable decrease in the invisible loss occurring during milling and a proportionate increase in the total yield of mill products.

The higher total yields of mill products were associated with the higher relative humidities and with the wheats of lower moisture content. These higher yields in the former case were undoubtedly due to decreased evaporation during milling of the moisture contained in the wheat and probably to the absorption of some moisture from the atmosphere by some of the mill stocks; and, in the latter case of lower moisture content wheats, to the greater amounts of water which it was necessary to add in tempering these wheats in order to bring their moisture contents to the required percentage. Each 10 per cent increase in relative humidity above 35 per cent increased the total weight of the products obtained about one-half of 1 per cent, and each decrease of 1 per cent in the moisture content of the wheat before tempering caused about six-tenths of 1 per cent increase in yield. Compared with the weight of the wheat before tempering, the samples containing from 9 to 9.9 per cent moisture showed a net gain in weight of total mill products for all relative humidities given, while the samples containing from 12 to 12.9 per cent moisture before tempering showed a net loss in weight of total mill products except for relative humidities higher than 60 to 69 per cent.

No very pronounced relation between the moisture content of the flour and that of the wheat before tempering was shown, or in other words, no relation was shown of moisture content of flour to the quantity of temper water added to the wheat. On the other hand, a decided tendency was shown for the moisture content of the flour to increase as the relative humidity increased, a difference of 10 per cent in relative humidity, making an average difference of approximately one-half of 1 per cent in the moisture content of the flour.

No definite relation between air temperature and total yield of mill products was established.

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